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A TECHNOLOGICAL SURVEY

OF VISION BLOCK MATERIALS

AND DESIGN

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REPORT PREPARED BY R. M. ECKERMAN

AEROFAB COMPANY, INC.

A TECHNOLOGICAL SURVEY
OF VISION BLOCK MATERIALS
AND DESIGN

DETROIT ORDNANCE DISTRICT
CONTRACT No. DA-20-018-ORD-23389
DEPARTMENT OF THE ARMY
OMS 5510.12.25500.13
OMS 5510.12.24100.03

This investigation conducted under
the supervision of
JOHN M. REYNAR
ORDMC-REM.2

OCTOBER, 1962

REPORT PREPARED BY R. M. ECKERMAN

AEROFAB COMPANY, INC.

2335 GOODRICH ST. • FERNDALE 20, MICHIGAN

In fulfillment of Contract DA-20-018-23389 for
the development and fabrication of Direct Vision Blocks
with improved optical characteristics and superior
ballistic attenuation, Aerofab Company has fulfilled
Phase I, of the contract and has arrived at the con-
clusion that Phase II need not be executed at this time.
The Project Engineer for Ordnance and the Contracting
Officer have concurred in the recommendation that work
be limited to the first phase and that the results of
extensive investigation, fabrication, and ballistic
testing be included in a final report for record.

Preliminary reports of salesmen and represent-
atives of both plastic and glass companies indicated that
materials were now available which could produce vision
blocks to meet the high standards now needed in Military
armored vehicles. This investigation has explored the
materials field in both glass and plastic. Specimens of
the best products available, have been procured and
prototype vision blocks have been fabricated. A massive
mounting fixture was constructed to evaluate the ballistic
properties on a firing range. The fabricated vision
blocks were subsequently tested with both armor piercing
and ball ammunition.

Currently two types of vision blocks are produced
by industry. The characteristics of these are covered by

Spec MIL-B-11352 B. The two types are:

> Type I. Laminated plate glass body
>
> Type II. Solid plastic body, with plate glass laminated to the front and back vision areas.

The Type I vision block has been in production since the early stages of World War II. Until recently, production of this style was restricted to the two largest producers of glass in this country. One of these companies was materially dominant during this period. As a result of this, product improvement was at a standstill. The early laminated glass vision blocks during this period, had a light transmission of less than 70% in the visible range. Currently this has been increased to 75%. The glass vision blocks have a tendency to develop stress relieving cracks in the plie. Resolution is inadequate and weight excessive. As an example, Vision Block #6300790, steel cased, weighs 6.4 lbs. An equivalent all-plastic vision block weighs 3.2 lbs.

The second type, herein referred to as the plastic body vision block is an adaptation of the plastic body periscope. It is generally recognized that this type must have a glass cover plate attached to the front and back vision areas. The reason for this is twofold:

1. Scratch resistant vision areas are required to prevent optical deterioration from surface abrasion.

2. The flatness of plate glass is superior to that readily obtainable on machined and polished plastic surfaces. Therefore bonding the glass to the plastic bridges surface irregularities and the resolution is permanently improved by this lamination. Holding the glass ajacent to the plastic, with a separating air space, as pointed out, does not result in improved resolution. The air separated surfaces are also susceptible to condensation and dust accumulation, with concurrent reduced vision. The ability to satisfactorily bond glass to plastic is therefore an unavoidable necessity.

In examining the requirements for satisfactory bonding of this nature, the following characteristics must be met:

1. Optical clarity

2. The suitability to production manufacturing

3. Physical stability (shock resistance and temperature adaptation)

The physical and optical characteristics must remain acceptable throughout an ambient temperature of -65°F to 160°F.

Physical Stability:

The most apparent characteristic that this bond must have is the ability to compensate or distribute the strain resulting from the differential expansion of glass and plastic. See exhibit A. Of necessity this interlayer must therefore be elastomeric.

Optical Clarity:

Optically this elastomeric interlayer should closely match the refractive index of the plastic, have high light transmission in the visible spectral range and not degrade the system resolution.

Suitability to production manufacturing:

The interlayer system assembly must be of a nature that can be economically accomplished.

Another characteristic that this elastomeric film must have, is to be completely free of solvents, monomeric residules, plasticizers, etc. Materials of this nature have a tendancy to migrate throughout the system, causing physical and optical degradation.

In selecting an interlayer two choices are apparent.

1. The bonding of a previously prepared film, to the system components.

2. Producing the film, while the system components are held in juxtaposition.

The Bonding of Prepared Films

Investigation has disclosed severe material limitations in bonding a prepared film. Of all of the films previously used in glass laminating, polyvinyl butyral is the only one that has proved satisfactory for safety glass construction. Previous experience, and the volume production of plastic body vision devices using

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polyvinyl butyral as an interlayer, have disclosed
serious limitations for this material. Delamination and
severe optical degradation have taken place during
storage. This is probably due to plasticizer migration
from the interlayer to the plastic. A plasticizer free,
prepared film elastomer reported by Frankford Arsenal, Dow
Corning Silicone Q-3-0105, looked interesting. However
this material was withdrawn by the manufacturer prior to
this evaluation.

All of the known producers of plastics were contacted
without a single recomendation of suitable material of the
prepared film type.

Producing an Interlayer Film in Place

To produce a film while the glass and plastic
are held in juxtaposition, necessitates the use of an
interlayer material sufficently liquid initially, to be
injected into the interlayer space. After the interlayer
material.is in place, it must be capable of undergoing a
physical or chemical change to greatly increase its stability
so as to form a firm elastomeric interlayer, with the
aforementioned characteristics.

Two types of materials were investigated:

A. Polymerizing Types

b. Reaction Types

Polymerizing Types

Only two general groups of polymerizing materials were available. These were the methacrylates and vinyls. Low temperature evaluation of the methacrylate group did not disclose sufficiently good low temperature flexibility. The one outstanding polymerizing type elastomeric interlayer material tested to date, is a vinyl copolymer produced by Minnesota Mining & Manufacturing Corporation under the trade designation of HC 917. This material is supplied by the manufacturer as a clear syrup. This syrup is polymerized with either ultraviolet or infrared radiation. 3M will supply data relating to the use of HC 917.

Reaction Types

The following reaction type groups were tested, with results as noted.

        A. Polysulphide polymers

        B. Urethane polymers

        C. Polysulphide - epoxys

        D. Epoxys

Polysulphide polymers

The polysulphide polymers could possibly, with extensive modification, produce usable interlayer films. This would depend on developing a clear, solvent free activator in contrast to the opaque solvent dispersions

presently used. The basic polymer would require the removal of contaminants in the present clear types. This could undoubtedly be accomplished by either molecular fractionation of the present material, or producing it in an all-glass apparatus. Both of these developments are outside the scope of this investigation.

Urethane Polymers

The Urethane polymers would require better low temperature flexibility, the development of a bonding adhesive, and optically clearer types. This group is not regarded as promising in the present or near future.

Polysulphide - Epoxys

The addition of Polysulphide polymer to epoxy resins does not produce low temperature film flexibility, of the order required. This combination is not thought to be promising.

Epoxys

Until recently the cured epoxy resins were excessively rigid for an elastomeric film application. However a highly flexible modification has been produced by Shell Chemical Company. This is their Epon X93. This material was developed for bonding implosion shields to television picture tubes.

Summary of Interlayer Investigation

Of the foregoing interlayer materials, there were

only two that warranted testing in vision blocks. These
were 3M's HC 917 (similar to Sunweld) and Shell Chemical
Companys Epon X93.

Concurrently with the interlayer evaluation, a
massive steel fixture was constructed to hold two
rectangular vision blocks in position, for ballistic test-
ing. The size and shape of these blocks conform to that
of vision block #6300790, except that the ends are square
instead of rounded. See exhibit B and C. This shape would
be comparative in evaluation between the test blocks and
the current production types.

21 test blocks were fabricated as specified by
Phase I,(1) and Phase I,(2) as follows:

Phase I,(1);

A. Test configuration vision block made from
laminated plies of 1/2" plate glass. The
interlayer lamimant was X93.

B. Same as Λ except that HC 917 was used as a
lamimant.

C. Same as Λ except that the edges of the glass
plies we.e not ground smooth, to accurately
conform to the shape of the holding fixture
cavity. The unground edges presented a "Stair
step" configuration adjacent to the holding
fixture cavity.

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D. Same as C except that HC 917 was used as a laminant.

E. Same as A except that 1/4" plate glass was used.

F. Same as B except that 1/4" plate glass was used.

G. Same as C except that 1/4" plate glass was used.

H. Same as D except that 1/4" plate glass was used.

I. Same as A except that 1/4" tempered plate glass was used.

J. Same as C except that 1/4" tempered plate glass was used.

K. Production vision block #6300790.

L. Block ground to shape out of a solid block of high density lead glass.

Phase I,(2);

M. Block machined from a solid piece of methyl methacrylate.

N. Solid methyl methacrylate core with 1/4" plate glass faces. The interlayer laminant was X93.

O. Same as N except that the laminant was HC 917.

P. Same as N except that tempered glass was used.

Q. Same as O except that tempered glass was used.

R. Same as N except that the inner face was made of 1/4" conventional safety glass.

S. Block machined from 1" plies of allyl Carbonate. X93 was used as a laminant. A solid block of allyl carbonate, of sufficiently large dimension, was not available. The 1" plies were therefore used with 1/4" plate glass face.

T. Same as S except that 1" plies of methyl methacrylate were used with 1/4" plate glass face.

U. Block laminated from 1" plies of polyester resin with 1/4" plate glass face.

V. Block laminated from 1" plies of stretched acrylic with 1/4" plate glass face.

The vision blocks, as listed, were ballistically tested with a NATO rifle and A P ammunition, at a range of 100 feet. The test fixture held the blocks in a comparable position to that of usual cupola installation. The block face presented an oblique surface to the line of projectile travel, at approximately 25° incidence. The attenuative results of blocks A through K, M through R, and T and V, were surprisingly similar. Without exception the first shot did not penetrate or cause spauling of the inner face. The second shot would penetrate if the point

of impact was within the destructive zone of the first shot. In every case the third shot would penetrate and would reduce the residual armor and vision to an ineffective level. The safety glass inner face on block R had less spauling than the solid glass cover plates. This feature should be further pursued, for possible inclusion in the applicable specification. The 25° angle of incidence caused the projectile to deflect towards the top of the block, which resulted in increasing the length of the projectile path through the block. In some cases the projectile penetrated the top of the block and imbedded in the armor - especially when impact was in the upper half of the vision block.

Block L exhibited extreme frangibility. This condition may possibly be corrected by normalizing.

Block M had lower attenuation than these with a front glass face, and the projectile path did not deflect as in the other blocks. The conclusion is that the glass face causes this change in projectile direction.

Block S showed greater frangibility than the methyl methacrylate group. The resulting attenuation was appreciably less.

Blocks T and V exhibited similar attenuation except that block V showed less frangibility. The projectile hole did not have the shattered appearance of

regular methyl methacrylate. The residual vision was therefore better.

Block U had less projectile attenuation than the methyl methacrylate or glass group.

The residual vision of blocks with tempered glass components was nil after the first shot.

From the foregoing the following observations are made:

1. Methyl methacrylate in either regular or stretched form offer the best combination of characteristics.

2. An inner face of safety glass reduces spauling and secondary fragmentation.

3. The use of tempered glass does not improve ballistic attenuation but does reduce residual vision.

4. Either HC 917 or X 93 will produce suitable laminations. From a production standpoint HC 917 is easier to use.

5. Inasmuch as the present vision block thickness offers protection for a maximum of two shots, future blocks should be designed with increased thickness. The area should be kept to an absolute minimum. Two small blocks offer more protection and residual vision, than one of

twice the size.

CONCLUSIONS:

The limited firings of this investigation indicate that materials commercially available for use as ballistic windows are not appreciably better than the laminated glass and the plastic vision blocks covered by Type I and Type II of Specification MIL-B-11352B. Plastic blocks without exterior and interior glass faces are not adequate for stopping A P projectiles from either .30 - 06 or NATO .762 weapons. None of the vision blocks of the above specification, or as modified in this endeavor, offers protection for more than one shot. If the second shot, falls within the major distructive area of the first shot, either penetration, or secondary fragmentation will result. Residual vision after the first shot depends on the location of impact. In most cases monocular vision area will remain. For practical purposes 100% destruction of the vision area will result from a second shot.

Inasmuch as the probability of projectile impact is a direct function of target size, it follows that the size of the vision block should be as small as possible for binocular vision. The problem of bonding the glass faces to the plastic body would be greatly reduced by a smaller area vision block. Improved visual aspect should result from increasing the number of vision blocks and not the

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individual block size. If the number of blocks is increased in the cupola, a resulting increase in armor structure will be required. Geometrically this can only be done by increasing thickness. The vision block could also be thickened, therefore offering more potential ballistic attenuation.

A new engineering approach to retaining the vision block in the cupola could result in an improved mounting system. This redesign could remove the jaming now experienced, on occasion, with the present mount. Another desirable feature would be to have an armor plate that could be placed over an empty block cavity when necessary. It would be most desirable to be able to insert the armor block as well as replacement vision blocks from inside the vehicle.
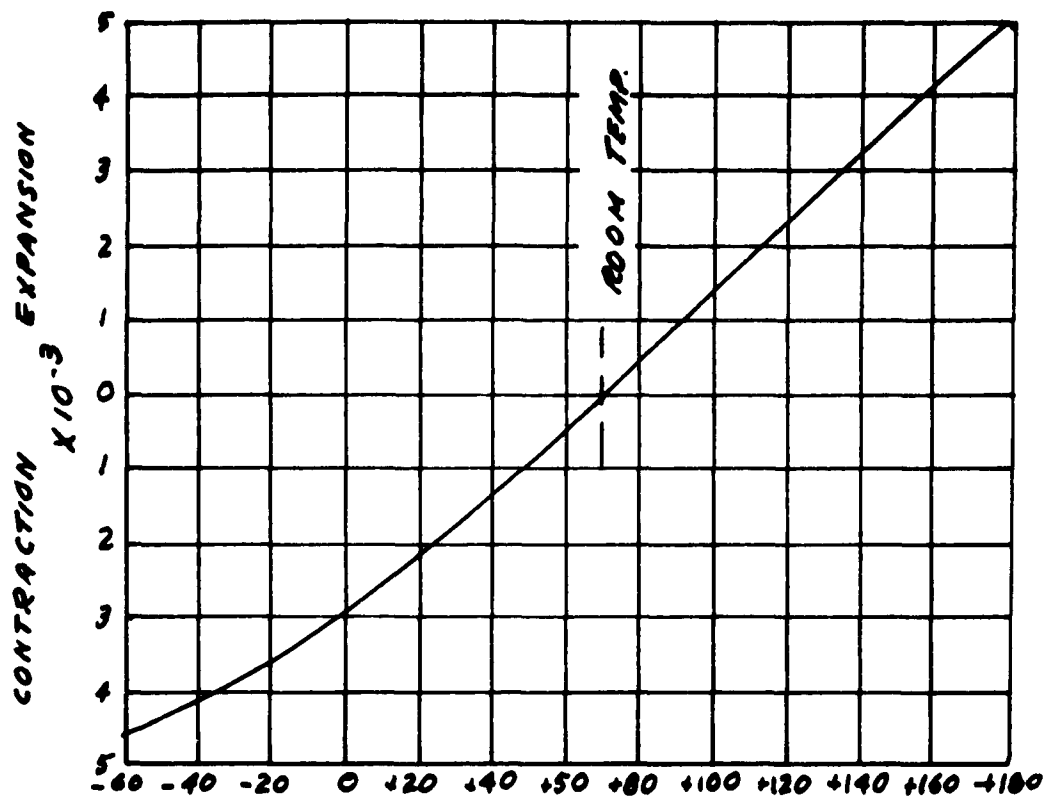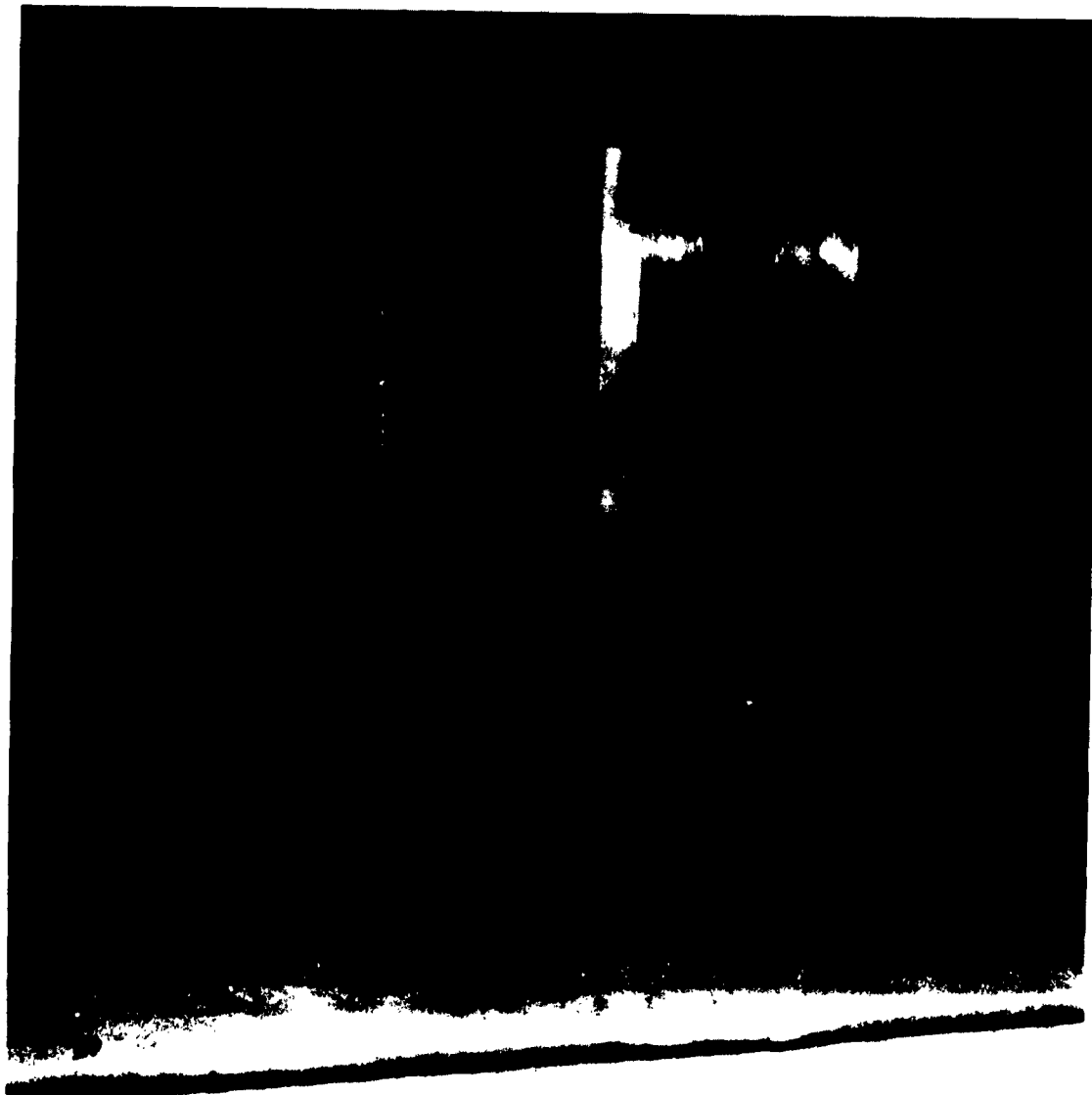
TEMPERATURE °F
DIFFERENTIAL ELONGATION OF PLASTIC & GLASS
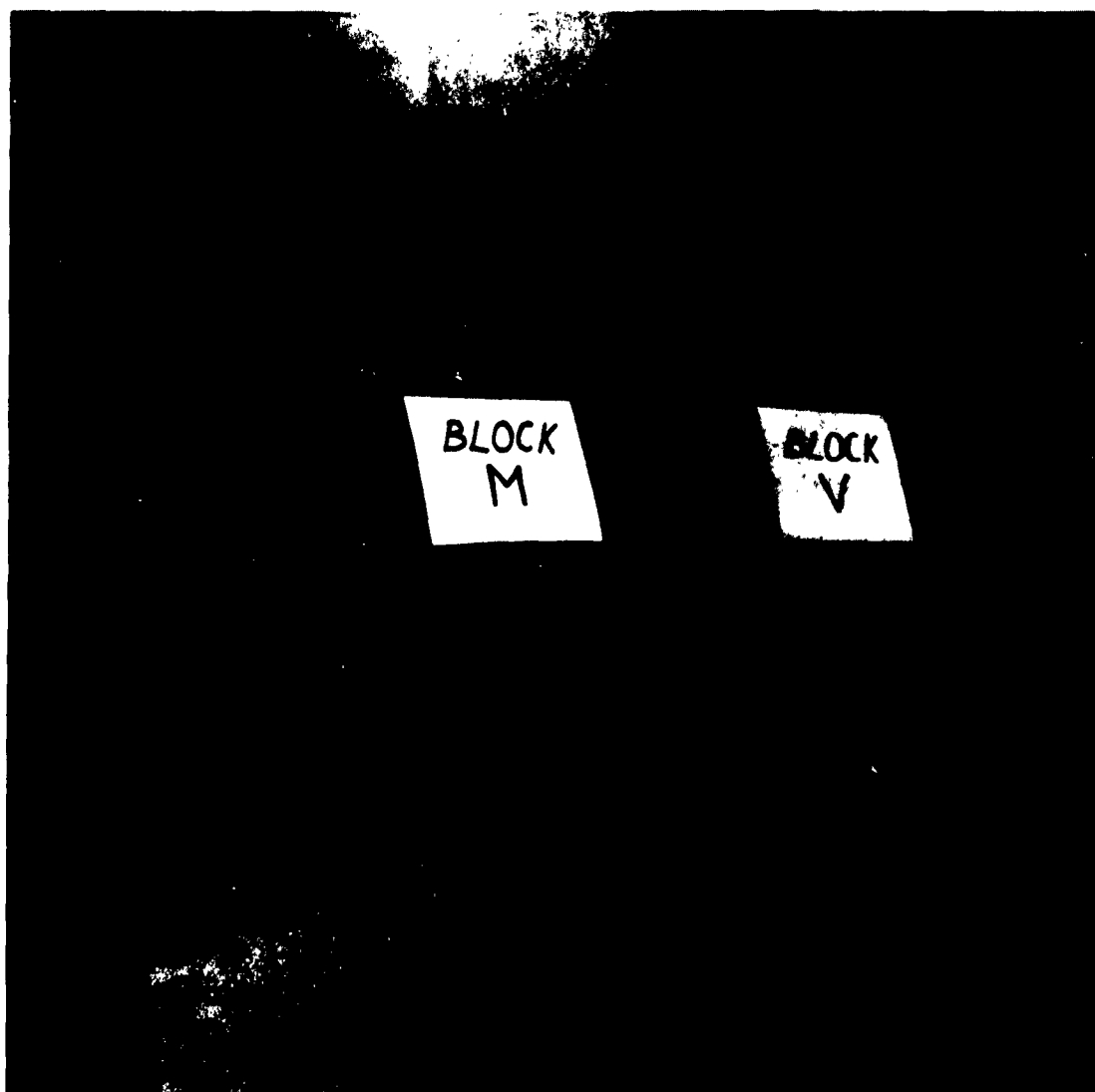THROUGHOUT AMBIENT TEMPERATURE RANGE

(EXHIBIT A)
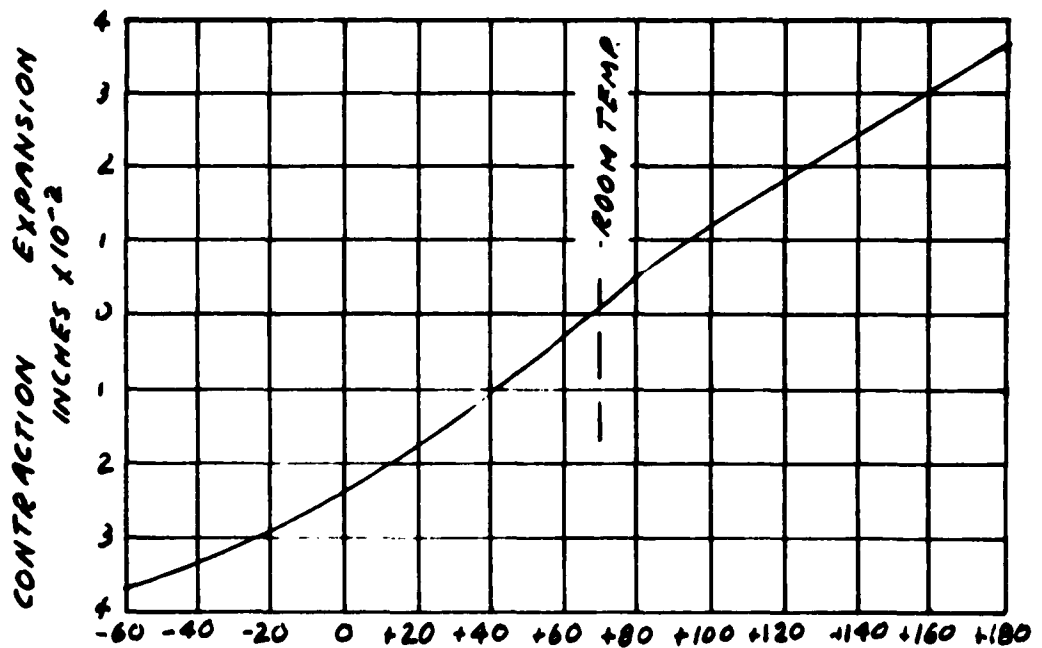
TEMPERATURE °F
DIFFERENTIAL ELONGATION OF PLASTIC & GLASS
ACROSS VISION BLOCK # 6300790

VISION BLOCK   TEST BLOCK
6300790   M

EXHIBIT B

I SHOT 100 FEET NATO AP IMPACT
AT X

EXHIBIT C